UNITED STATES DISTRICT COURT
DISTRICT OF MINNESOTA

REGENTS OF THE UNIVERSITY OF MINNESOTA, Plaintiff, v. AT&T MOBILITY LLC, Defendant, ERICSSON, INC., and ALCATEL LUCENT USA INC., Defendants-Intervenors.	Civil Action No. 14-cv-4666 JRT-TNL **JURY TRIAL DEMANDED**
REGENTS OF THE UNIVERSITY OF MINNESOTA, Plaintiff, v. SPRINT SPECTRUM L.P., et al., Defendants, ERICSSON, INC., ALCATEL LUCENT USA INC., and NOKIA SOLUTIONS AND NETWORKS US LLC, Defendants-Intervenors.	Civil Action No. 14-cv-4669 JRT-TNL **JURY TRIAL DEMANDED**

REGENTS OF THE UNIVERSITY OF MINNESOTA, Plaintiff, v. T-MOBILE USA, INC., Defendant, ERICSSON, INC., ALCATEL LUCENT USA INC., and NOKIA SOLUTIONS AND NETWORKS US LLC, Defendants-Intervenors.	Civil Action No. 14-cv-4671 JRT-TNL **JURY TRIAL DEMANDED**
REGENTS OF THE UNIVERSITY OF MINNESOTA, Plaintiff, v. CELLCO PARTNERSHIP D/B/A VERIZON WIRELESS, Defendant, ERICSSON, INC., and ALCATEL LUCENT USA INC., Defendants-Intervenors.	Civil Action No. 14-cv-4672 JRT-TNL **JURY TRIAL DEMANDED**

DECLARATION OF JONATHAN WELLS, PH.D.,
RELATING TO CLAIM CONSTRUCTION

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INDEX OF EXHIBITS

<u>**EXHIBIT**</u>	<u>**DESCRIPTION**</u>
A.	U.S Patent No. 7,251,768
B.	U.S. Patent No. RE45,230
C.	U.S. Patent No. 8,588,317
D.	U.S. Patent No. 8,718,185
E.	U.S. Patent No. 8,774,309
F.	*Curriculum vitae of* Dr. Jonathan Andrew Wells, dated Oct. 2021
G.	‘935 Request for Provisional Application Under 37 C.F.R. § 1.53(c), dated April 22, 2002
H.	‘886 Request for Provisional Application Under 37 C.F.R. § 1.53(c), dated April 22, 2002
I.	Excerpt from *Linear Combination*, *Collins Dictionary of Mathematics* (2nd ed. 2002)
J.	Excerpt from David Poole, *Linear Algebra: A Modern Introduction* (2nd ed. 2006)
K.	U.S. Patent No. 6,188,717 (Kaiser Patent)
L.	Excerpt from the ’768 Patent File History, Office Action dated Oct. 5, 2005
M.	Excerpt from the ’768 Patent File History, Office Action response dated Jan. 5, 2006
N.	Gao & Zhou, “Secure MIMO communication system based on time varying linear transformation,” *Proceedings of Third Int’l Conf. on Wireless, Mobile and Multimedia Networks* (2010)
O.	Gao, “A Novel MIMO communication system based on time varying linear transformation and Tanner codes,” *Proceedings of 2010 IEEE 10th Int’l Conf. on Signal Processing* (2010)

P. Chen, et al., "Turbo Space-Time Codes with Time Varying Linear Transformations," *IEEE Transactions on Wireless Comm.* (2007)

Q. Zhou, "A novel space-time LDPC code with Time varying precoding," *Proceedings of 2nd Int'l Conf. on Wireless, Mobile and Multimedia Networks* (2008)

R. Kenneth Andrews, Chris Heegard, & Dexter Kozen, "A Theory of Interleavers," *Technical Report TR97-1634*, Computer Science Dep't, Cornell Univ., June 1997

S. Frank Hargrave, Hargrave's Communications Dictionary (2001)

T. *Intentionally Left Blank*

U. ETSI TS 136.211 V10.0.0 (2011-01) Section 6.8.5

V. Excerpt from Cox, An Introduction to LTE: LTE, LTE-Advanced, AEO and 4G Mobile Communications

W. Excerpt from Louis Litwin & Michael Pugel, "The Principles of OFDM," *RF Signal Processing*, January 2001

X. Excerpt from Jeroen Theeuwes, Prank H.P. Fitzek, Carl Wijting, "Subcarrier Assignment for ODFM Based Wireless Networks Using Multiple Base Stations," Aalborg Univ., ISBN 87-90834-49-6 (2004)

Y. Excerpt from Klaus Witrisal, OFDM Air-Interface Design for Multimedia Communications (2002), ISBN: 90-76928-03-7)

Z. National Instruments, "OFDM and Multi-Channel Communication Systems," http://www.ni.com/white-paper/3740/en/ (2014)

AA. Hu, et al., "Nonlinearity Reduction by Tone Reservation with Null Subcarriers for WiMAX System," Wireless Personal Communications, Vol. 54, Issue 2, (2010)

BB. IEEE Draft Standard for Local and Metropolitan Area Networks – Part 16 (802.16a) dated February 7, 2002

I, Jonathan Wells, declare as follows:

I. INTRODUCTION

1. My name is Dr. Jonathan Andrew Wells. I have been retained by Fish & Richardson P.C. on behalf of the Regents of the University of Minnesota ("University of Minnesota" or "Plaintiff") to provide expert opinions concerning certain technical issues relating to the meaning and construction of certain terms in the following five patents asserted by the University in the above captioned cases:

- U.S Patent No. 7,251,768 ("the '768 patent");[1]
- U.S. Patent No. RE45,230 ("the '230 patent");[2]
- U.S. Patent No. 8,588,317 ("the '317 patent");[3]
- U.S. Patent No. 8,718,185 ("the '185 patent");[4] and
- U.S. Patent No. 8,774,309 ("the '309 patent").[5]

2. This declaration sets forth the basis and reasons for my opinions from the perspective of an expert in the field of wireless systems. This Declaration is based on the information currently available and known to me. It may be necessary for me to supplement this declaration based on material that subsequently comes to light in this case, and I reserve the right to do so.

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[1] Attached as Exhibit A.
[2] Attached as Exhibit B.
[3] Attached as Exhibit C.
[4] Attached as Exhibit D.
[5] Attached as Exhibit E.

II. QUALIFICATIONS

3. My educational background, career history, publications, and other relevant qualifications provided here are only a summary. My full *curriculum vitae*, which includes cases where I have previously given testimony, is attached to this Declaration.[6]

4. I received a B.Sc. in Physics with Physical Electronics, awarded with first class honors, from the University of Bath in Bath, United Kingdom, in 1987. In 1991, I earned by Ph.D., also from the University of Bath. I earned my M.B.A., awarded with distinction, in 1998 from Massey University in New Zealand.

5. I have over 35 years of academic and industry experience in wireless networks (e.g., 2G, 3G, 4G, and 5G networks, which includes GSM, WCDMA, LTE, and NR technologies), cellular infrastructure equipment (handsets, base stations and backhaul), and wireless standards, rules and regulations (e.g., 3GPP, ETSI and FCC). Over my career, I have worked with companies to develop and deploy radio frequency (RF) hardware for telecommunication infrastructure equipment for worldwide export, to implement marketing and product development strategies for cellular wireless products, and to participate in European Telecommunications Standards Institute ("ETSI"), Federal Communications Commission ("FCC"), and other technical body meetings.

6. I began my career in 1985, as an Engineer for Plessey Research, Caswell, United Kingdom, developing high-speed fiber optic transmitter/receiver devices. In 1987,

[6] Attached as Exhibit F.

I worked at British Aerospace, Filton, Bristol, United Kingdom, designing and fabricating novel mixer devices, to support my Ph.D. research.

7. From in 1990 to 1992, I worked at the University of Bath, as a Post-Doctoral Research Officer. During this time, I designed and fabricated novel quantum amplifiers in a clean room environment and developed computer models to predict semiconductor device performance. I also taught undergraduate classes and ran laboratory sessions.

8. In 1993, I joined Matra Marconi Space, Portsmouth, United Kingdom, as a Senior Design Engineer and developed a GaAs MMIC mixer and MIC transmitter board for two satellite payloads and performed theoretical analysis and modeling of low noise VCOs.

9. From 1994 to 1998, I worked for MAS Technology (now Aviat Networks), Wellington, New Zealand, first as Senior RF Design Engineer and later as RF Group Manager. I was responsible for RF hardware development for cellular and telecommunications applications; developed three generations of wireless transmission, switching, and multiplexing products; and designed and sustained responsibility for satellite ground station terminals. I personally designed a wide range of RF devices and was responsible for the company's European regulatory approvals.

10. In 1998, I joined Adaptive Broadband (now GE Digital Energy), Rochester, New York, first as Engineering Group Leader and later as Director Wideband Products. I was responsible for the Terrestrial Infrastructure Group, providing telecommunications products for cellular and private network applications; managed P&L responsibility for

$4M wireless division; and was responsible for the development of a family of digital radios and associated switching/multiplexing equipment.

11. From 2000 to 2004, I worked for Stratex Networks (now Aviat Networks), San Jose, California, as Director Product Development. I was responsible for global product development of high-end digital microwave radios primarily for cellular backhaul applications; led RF/microwave development team of 35 engineers based in two continents; performed technical leadership of flagship Eclipse product, shipping over 250,000 units; and was responsible for technical management of overseas manufacturing subcontractors.

12. In 2005, I joined GigaBeam Corporation, Herndon, Virginia, as Director Product Management and Global Regulatory Affairs. At GigaBeam, I was responsible for overall product strategy for a novel, industry-transforming wireless communication product. I had responsibility for establishing a global regulatory framework for this new product, which included developing FCC, CEPT, and ETSI standards to cover the specification and regulation of the system. I participated in multiple FCC, CEPT, and ETSI standard setting meetings, and personally met multiple times with over a dozen different international regulatory bodies to help setup wireless regulations within their countries.

13. Since 2007, I have been an independent consultant with AJIS Consulting, where I provide independent technical consulting on wireless communications and emerging wireless fields. The services I provide include: acting as a technical expert support of 2G, 3G, 4G, and 5G cellular and wireless patent litigation; providing analysis

of cellular and mobile wireless patents and infringing equipment; providing cellular and wireless technology technical and industry analysis for companies, analysts, and investment institutions, and researching and publication of analyst reports; providing wireless product development and marketing strategies; and providing specialized technical workshops.

14. I have written multiple books, industry reports and journal and conference papers, most of which focus on wireless communications systems. For example, I am the author of "*Multi-Gigabit* Microwave *and Millimeter-Wave Wireless Communications*" (Artech House, 2010). I have authored four comprehensive industry reports on cellular connectivity for Mobile Experts. I am also a listed inventor of several patents and am an author of over 40 academic and commercial publications and presentations.

15. I have lectured as part of undergraduate programs at UC Berkeley, Carnegie Mellon University, and University of Bath, and have given over two dozen lectures and conference presentations on topics germane to wireless communications. I have lectured as part of undergraduate programs at University of California, Berkeley, Carnegie Mellon University, and University of Bath, and have given over two dozen lectures and conference presentations on topics germane to wireless communications.

16. I have been a member of the Institute of Electrical and Electronic Engineers (IEEE) since 1995 and was elected as a Senior Member in 1999. In 2019, I was recognized by the IEEE Santa Clara Valley Section, one of the largest IEEE Sections in the world, as their 2019 "Outstanding Engineer." This was awarded "[f]or [my] acknowledged expertise in the field of wireless communications and wireless technology,

for his willingness to mentor others in the field, and for his work in the development of the next generation of creative and innovative technical products."

III. BASIS FOR OPINIONS

17. The opinions expressed herein are based on my training and experience in the area of wireless communications systems, and upon my review of the five patents-in-suit, their file histories, and numerous other materials referenced throughout this Declaration.

IV. TECHNOLOGY BACKGROUND

18. In a cellular network, the "cell tower" and cell phones communicate with each other by transmitting and receiving radio waves. The transmission from the cell tower to the cell phone is called the "downlink" and the communication in the other direction is called the "uplink." The infringement allegations in this case involve techniques used in downlink and uplink communications in Defendants' 4G/LTE and 5G/NR networks.[7]

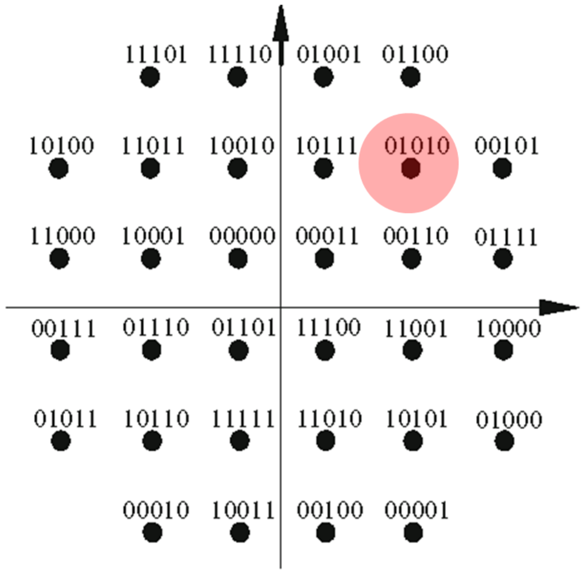
A. Wireless Transmission Overview

19. One of the primary drivers for the development of LTE was to improve the internet-based services, such as mobile applications, communications of video and audio files, etc., that could be supported by mobile devices. These internet-based services require the communication of digital data—streams of 1s and 0s—over a wireless

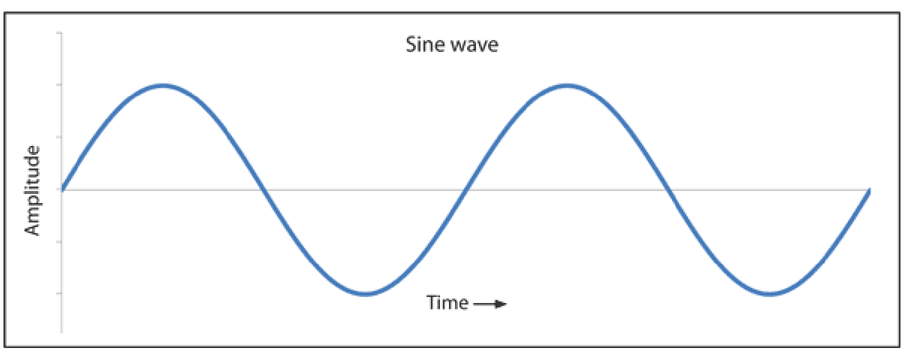
[7] "LTE" stands for Long Term Evolution and is the dominant 4th generation technical standard for cellular networks in the world today. LTE is sometimes referred to as "4G." "NR" stands for New Radio and is dominant 5th generation technical standard for cellular networks in the world today. NR is sometimes referred to as "5G."

connection. To achieve higher data rates, combinations of these 1s and 0s (often called "bits" of data), are converted into "symbols" for transmission. For example, two bits can be arranged in four different combinations (*i.e.*, 00, 01, 10, and 11). In this example, symbols corresponding to one of these four different combinations, would be transmitted over each symbol interval. Symbols corresponding to larger combinations that contain more bits can be used to further increase the amount of information communicated at a time. In LTE and 5G, this concept is extended, in some cases, to the transmission of up to 8 bits of digital data over each symbol interval, which requires an "alphabet" of 256 different symbols. While increasing the amount of information that can be transmitted with each symbol can increase the network speed, it can also make it more difficult for the mobile device to determine which symbol it received if the signal is weak or altered by interference.

20. Symbols are often visualized in an X-Y diagram. The points in the diagram each represent a different symbol, and the collection of symbols is often called a "constellation." In the example below, the constellation has 32 symbols that represent different combinations of five bits. The distance of each point from the origin of the X-Y diagram graphically represents the "amplitude" of symbol and the direction from the origin to the point represents the symbol's "phase." For example, the point highlighted in red has coordinates (3,3), which corresponds to an amplitude of $3*\sqrt{2}$, and a phase of 45 degrees. Some of the disputed terms relate to the manipulation of the symbol's amplitude and phase before transmission.

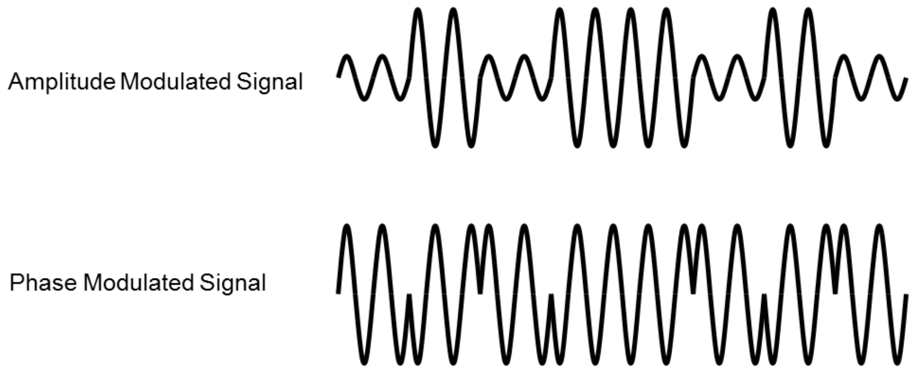


21. After the bits of data have been "mapped" to the various symbols in the constellation, the symbols are further modified before transmission. Many of these modifications are the subject of the asserted patents and described in more detail later. A transmitter then "modulates" a radio wave to communicate the information in the symbols. The modulated radio wave, also called a "carrier wave" or "carrier signal" starts as a regular cyclical (or "sinusoidal") waveform:



This carrier wave is then "modulated" by varying one or more of its properties, such as changing the height of wave (or its "amplitude"), the starting point (in time) of the wave

(called its "phase"), or both, to represent each successive symbol. Examples of an amplitude modulated signal and phase modulated signal are shown below:



When the receiver receives the modulated radio waves, it can detect the amplitude and phase of the wave and thus determine the data that was transmitted (a process called "demodulation").

B. Interference in Wireless Communications

22. Ideally, the received radio signal would be identical to the signal that was transmitted, thereby making the process of demodulation straightforward. In the real world, however, the received signal can be distorted in a variety of ways that interferes with the receiver's ability to accurately reproduce the transmitted data due to environmental factors, such as interference, physical obstructions, or reflected signals. For example, these distortions can cause "fades"—or the temporary loss of the signal at the receiver—that can prevent data from being received. To guard against this possibility, it is common to modify or "code" the data in various ways so that extra "redundant" data is also transmitted. Consequently, if portions of the transmission are lost, it may be possible for the receiver to use the redundant data to recover the lost data. Because the vulnerability of a transmission signal to distortion becomes greater as the

data rate increases, or as the distance from the transmitter to the receiver increases, coding techniques that guard against fading can improve both the speed and effective range of a digital transmission.

C. Transmission Over Multiple Channels and Multiple Antennas

23. In early wireless communication systems, it was common for digital transmissions to occur over a single "channel" between a transmitter and receiver. In other words, a single sequence of digital values would be transmitted from the transmitter to the receiver. In these systems, coding was typically limited to "error control coding." Later, researchers developed technologies that allow data to be transmitted over multiple parallel channels between a transmitter and a receiver. One such technology is called "multi-carrier" transmission. In a multi-carrier system, the transmitter transmits multiple modulated carrier waves, called "subcarriers," at the same time but at different frequencies, thereby allowing two or more parallel sequences of data to be sent at the same time. One such multi-carrier technique, used in a preferred embodiment of the patents-in-suit, is called "Orthogonal Frequency Division Multiplexing" or OFDM. Another technique used in some embodiments, called Multiple Input Multiple Output (MIMO), involves the use of multiple transmission antennas to transmit multiple parallel sequences of data that are received over multiple antennas.

V. THE PATENTS-IN-SUIT

A. Summary of the '230 and '768 Patents

24. The inventions of the '230 and '768 patents are directed to coding techniques that improve the performance of a wireless transmission system. The claimed

techniques all involve a type of coding called "linear precoding." Linear precoding entails creating different weighted sums of a given block of symbols and transmitting those different sums over parallel transmission channels (e.g., MIMO or OFDM). A weighted sum of a set of values is the result of multiplying each value by some number (a weight), and then adding the results together. For example, given three values A, B, and C, a weighted sum might be 3A + 2B + 5C. In the preferred embodiments of the '230 and '768 patents, linear precoding is combined with two other techniques, called "interleaving" (rearranging the order of bits or other symbols in a data stream) and "error control coding" (adding additional bits to a data stream to provide redundancy). These techniques provide an overall improved coding system.

25. One convenient way to define the operation of a precoder is by using a mathematical construct called a "matrix." A matrix is simply a rectangular grid with columns and rows of values, as shown below. In this example, there are three rows and two columns of values. Each value in a matrix is also called an "element."

$$\begin{bmatrix} -1.3 & 0.6 \\ 20.4 & 5.5 \\ 9.7 & -6.2 \end{bmatrix}.$$

26. One special type of matrix is called a "vector." Vectors are matrices that have only a single column of values.

27. Matrices are useful to describe the arithmetic operation of precoders because there are well-defined rules for adding and multiplying matrices. In other words, the arithmetic expressions of matrices can be used as shorthand to describe a series of

operations performed by the precoder on the matrix elements. Precoders are typically described (and are described in the ’768 and ’230 patents) by defining a vector of input values and then defining the precoder itself as one or more matrices of values that will be applied to the input values in the vector to create different weighted sums of those inputs. In the following matrix multiplication expression, for example, an input vector (which is the second matrix with the values x and y) can be multiplied by a precoder (which is the first matrix that contains the values a through d) to create two different weighted sums of the inputs *x* and *y*:[8]

$$\begin{bmatrix} a & b \\ c & d \end{bmatrix} * \begin{bmatrix} x \\ y \end{bmatrix} = \begin{bmatrix} a * x + b * y \\ c * x + d * y \end{bmatrix}.$$

28. In some cases, a precoder matrix may be described as a mathematical operation that involves more than one matrix. For example, a precoder matrix C might be defined as the product of two matrices A and B (i.e., A*B=C). Just as in ordinary arithmetic, multiplying vector X by precoder C is mathematically equivalent to multiplying the vector X by matrices A and B. In other words, C*X = (A*B)*X = A*(B*X). Thus, multiplication by a single matrix such as C can be used to provide the same result as successive multiplication by two different matrices (e.g., A and B).

29. The ’768 and ’230 patents describe several exemplary precoder matrices with useful properties. In one example, the ’230 patent describes a class of precoders referred to as “LCP-B,” which may be used in a MIMO transmission system. The patent

[8] The “*” symbol represents multiplication.

explains that LCP-B precoders may be described in terms of a precoder matrix Θ (theta) that is itself defined as the product of two component matrices by the following equation:

$$\Theta = F_{N_t}^{T} diag(1, \ \alpha, \ \dots, \ \alpha^{N_t - 1}), \alpha := \ e^{j2\pi/P}$$

30. In the equation for LCP-B, the two component matrices of Θ are $F_{N_t}^{T}$, which is a well-known special type of matrix called an "inverse fast Fourier transform" (IFFT),[9] and $diag(1, \ \alpha, \ \dots, \ \alpha^{N_t - 1}), \ \alpha := \ e^{j2\pi/P}$, which defines a type of matrix called a "diagonal matrix." A diagonal matrix has non-zero values only on its diagonal (elements that have the same row and column number), and in this case, those values are a sequence defined in terms of a constant α (alpha) raised to different exponential powers. Both matrices are square matrices of size N_t x N_t, where N_t is the number of transmission antennas in the system. Because of the rules of matrix arithmetic described above, multiplying a vector of values by Θ is equivalent to first multiplying it by the diagonal matrix, and then by the IFFT matrix.

31. Figure 1 of the '768 patent (reproduced below) shows an exemplary system that uses techniques claimed in both the '768 and '230 patents.[10] An "error control unit" first processes an output data stream, which modifies the data stream using error control coding to create a stream of coded bits.[11] The output of the error control unit then passes

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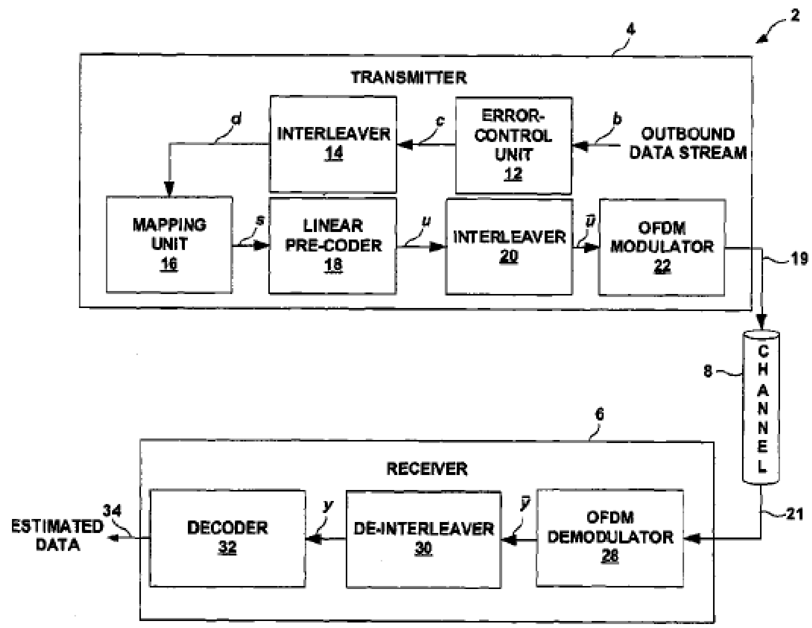
[9] The '230 patent defines the term F_{N_t} to be equal to "the Nt-point inverse fast Fourier transform (IFFT) matrix) whose (m,n)st entry is given by ${N_t}^{-1/2} e^{j2\pi(m-1)(n-1)/N_t}$. '230 Patent, Cert. of Correction at 6. It goes on to define Θ in terms of $F_{N_t}^{T}$, which is the transpose of F_{N_t}. Because the transpose of an IFFT matrix is simply itself, this change in terminology does not change the ultimate value of the matrix used in the equation.

[10] *E.g.*, '768 Patent at 3:35-38.

[11] '768 Patent at Fig. 1, 4:22-25.

through an interleaver, which rearranges the order of the coded bits to create interleaved bits.[12] Rearranging the bits guards against "burst" errors that affect a discrete portion of the stream of bits by more widely distributing the redundant data over a larger portion of the stream. The interleaved bits then pass through a "mapping unit" which generates a stream of constellation symbols based on the patterns of bits.[13] The symbols output by the mapping unit are then provided to a linear precoder, which combines them in various ways to create blocks of pre-coded symbols.[14] The block of precoded symbols is then provided to a second interleaver which rearranges the order of the pre-coded symbols.[15] The rearrangement by the second interleaver further spreads redundant data to subcarriers whose frequencies are spaced further apart.[16] This protects against errors that affect specific ranges of frequencies in a multi-carrier system. Finally, the pre-coded symbols are provided to an OFDM modulator, which uses the different precoded symbols in the block to modulate respective subcarriers for transmission using OFDM.[17] A receiver includes mechanisms for "demodulating" the received waveform to recreate the stream of precoded symbols, de-interleaving that stream, and then decoding it to recover the original stream of bits.[18]

[12] '768 Patent at Fig. 1, 4:33-35.
[13] '768 Patent at Fig. 1, 4:36-44.
[14] '768 Patent at Fig. 1, 4:44-49.
[15] '768 Patent at Fig. 1, 4:50-67.
[16] '768 Patent at 4:50-67.
[17] '768 Patent at Fig. 1, 4:55-60.
[18] '768 Patent at Fig. 1, 5:14-27.



32. The asserted claims of the ’768 and ’230 patents recite various required features of the structural elements of the transmitter (or corresponding method steps) in Figure above. Claim 1 of the ’768 patent is exemplary:

> A wireless communication device comprising:
> an error-control coder that applies an error correction coder to produce an encoded data stream of information bearing symbols;
> a bit interleaver to produce an interleaved data stream in which neighboring bits of the encoded data stream are positions to be mapped to different constellation symbols;
> a mapping unit to map the interleaved data stream to the constellation symbols, wherein the constellation symbols are selected form a constellation having a finite alphabet;
> a precoder that applies a liner [sic:linear] transformation to the constellation symbols to produce precoded symbols, wherein the precoded symbols are complex numbers that are not restricted to the finite alphabet of the constellation;
> a symbol interleaver to process the precoded symbols to produce permutted blocks of the precoded symbols; and

a modulator to produce an output waveform in accordance with the permuted blocks of precoded symbols for transmissions through a wireless channel.

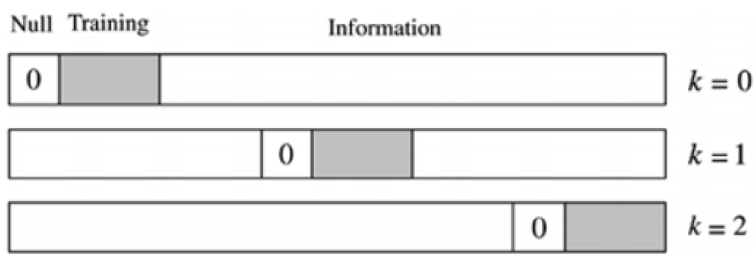
B. Summary of the '317, '309, and '185 Patents

33. The '317, '309, and '185 patents (collectively "the '317 family patents") are directed to techniques for "training" the receiver of a wireless communication to correct for certain non-ideal conditions in the wireless communication channel. This training is achieved by transmitting predefined values, called "training symbols," to the receiver at pre-defined time intervals. Because the receiver knows both the values of the training symbols and when to expect them, it can compare the values actually received to the values that were expected, and thereby determine how to adjust the received values to correct for the non-ideal conditions in the communication channel.

34. One type of training symbol discussed in the '317 family patents is called a "null subcarrier."[19] As its name suggests, a null subcarrier exists when no value is transmitted on a particular subcarrier in a multi-carrier transmission system. In general, the '317 family patents describe techniques for inserting training symbols, including null subcarriers, into blocks of "information bearing symbols" (i.e., message data) that are to be transmitted from the transmitter to the receiver.[20] The techniques involve the use of a "hopping code"—a formula whose value changes over time—to determine where in the blocks the null subcarriers will be inserted. *Id.*

[19] '317 Patent at 2:27-32.
[20] *E.g.,* '317 Patent at 4:24-31.

35. The figure below illustrates the basic concept. It shows three successive blocks of output symbols for transmission on three successive time steps (k = 0, 1, 2).[21] In each block, a hopping code is used to insert a null subcarrier (indicated by the symbol "0"), along with an adjacent block of other (non-zero) training symbols (indicated by the grey area) at a different position. The remainder of each block (the white space) represents information bearing symbols (i.e. user data) that will be transmitted along with the training symbols.[22]



36. The asserted claims of the '317 family recite various techniques for using hopping codes to insert training symbols, such as null subcarriers, into output blocks for transmission in OFDM (multi-carrier) and MIMO (multi-antenna) transmission systems. Claim 13 of the '309 patent is exemplary:

> A method comprising:
> encoding information-bearing symbols;
> forming two or more blocks of output symbols for orthogonal frequency division multiplexing (OFDM) transmissions over a multiple-input multiple-output (MIMO) channel, wherein the forming comprises inserting training symbols and null subcarriers within two or more blocks of the encoded information-bearing symbols at positions determined by a hopping code, wherein the hopping code is a function of the number of antennas for transmitting the transmission signals; and

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[21] '317 Patent at Fig. 3, 13:23-29.
[22] '317 Patent at 7:44-8:42.

transmitting, via two or more antennas, transmission signals in accordance with the two or more blocks of output symbols.

C. The Art to Which the Patents-in-Suit Pertain

37. I have been advised and understand that claim construction must be addressed from the point of view of a person having ordinary skill in the art to which a patent pertains. The five patents-in-suit all pertain to systems and methods for improving digital wireless communication systems. In my opinion, a person having ordinary skill in the art would be a person having ordinary skill in the art of digital wireless communications systems.

VI. DISCUSSION OF CLAIM TERMS

A. Linear Precoding Terms

38. Many claims in the ’768 patent recite a “precoder” that applies a “linear transformation” to constellation symbols.

1. A “Precoder” Produces a Weighted Sum of the Input Symbols

39. The ’768 patent specification describes “linear precoding” constellation symbols to improve diversity gains and system performance in an OFDM system with multiple subcarriers. The specification explains that “linear precoding” is a term of art that means “sending linear combinations of symbols” over a communication channel.[23] This is consistent with how the term “linear precoding” would have been understood by those having ordinary skill in the art of digital wireless communications systems in the

[23] Ex. G at 3-4 (Prov. App. No. 60/374,935 (the “’935 provisional”), which is incorporated by reference in the ’768 Patent at 1:7-12).

2002 time frame. It is also consistent with the teaching of the ’768 and ’230 patents to transmit different linear combinations of data symbols on parallel transmission channels, as shown by the following statements:

- “instead of sending uncoded symbols (one per subcarrier), our idea is to send different linear combinations”[24]
- “Each transmitted symbol in ST-LCP is a linear combination of the complex symbol entries in s.”[25]
- “[O]ur idea is to send linearly combined symbols on the subcarriers”[26]
- “transmitter 4 utilizes different linear combinations of the information symbols on the subcarriers.”[27]

40. A “linear combination” of values is, in turn, simply a weighted sum of those values, as would have been understood by those having ordinary skill in the art of digital wireless communications systems in the 2002 time frame.[28]

2. The Inventors’ Meaning for “Linear Transformation”

41. The term “linear transformation” appears in several claims of the ’768 and ’230 patents. A “linear transformation” is a mathematical term with a well-defined

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[24] Ex. G at UMN0000778 (’935 provisional).
[25] Ex. G at UMN0000818 (’935 provisional).
[26] Ex. H at UMN0000966 (Prov. App. No. 60/374,886 (the “’886 provisional”), which is incorporated by reference in the ’768 Patent at 1:5-12).
[27] ’230 Patent at 40:30-35.
[28] Ex. I at UMN0149588 (true and correct copy of an excerpt from *Linear Combination*, *Collins Dictionary of Mathematics* (2nd ed. 2002)). The definition of “linear combination” is “a sum of the respective products of the elements of some set with constant coefficients).

ordinary meaning in the field of matrix algebra: "a mathematical operation on vectors f(x), which has the property that for any vectors a and b that are valid arguments to f, f(a + b) = f(a) + f(b), and for any scalar k f(k*a) = k*f(a)."[29]

42. I understand that an inventor is entitled to be their own lexicographer and may also disclaim certain subject matter from the scope of a term in the specification or during prosecution of the patent. Based on my review of the prosecution history of the '768 patent, it is my opinion that a person having ordinary skill in the art would recognize that the inventors of the '768 patent disclaimed subject matter from the ordinary meaning of "linear transformation."

43. Specifically, during prosecution of the '768 patent, the examiner rejected the pending claims over U.S. Patent No. 6,188,717 issued to Kaiser.[30] The examiner argued that an element in Kaiser called the "spreading and sequence imposition unit (4)" corresponded to a "precoder that linearly precodes the encoded data stream."[31] Kaiser's "spreading and sequence imposition unit" implemented a signal processing method based on a technique called "spreading." Spreading entails converting a single data symbol into a stream of multiple data symbols by multiplying each symbol by a sequence of binary codes or "chips." The multiplication creates a series of data symbols called a "spread

[29] Ex. J at 211 (a true and correct copy of excerpts from David Poole, *Linear Algebra: A Modern Introduction* (2nd ed. 2006)).
[30] Ex. K (a true and correct copy of the Kaiser Patent).
[31] Ex. L at UMN0000200-201 (true and correct excerpt of the '768 Patent File History, Office Action dated Oct. 5, 2005).

sequence" with each value in the sequence representing the product of the original single symbol and one of the chips.[32]

44. In Kaiser, the system would process L symbols in parallel. Moreover, each spreading sequence had L chips (i.e., the number of chips equaled the number of symbols). The spread sequence and imposition unit would multiply each input symbol by a respective spread sequence, generating L coded values for each of the L input symbols (i.e., L^2 values in total). The spreading and sequence imposition unit would then "superimpose" the respective L sequences of coded values together to generate a final sequence of values.[33] In other words, Kaiser described a two-step process. The first step entailed spreading each input symbol with a sequence of binary chips to generate coded sequences and the second step entailed superimposing the spread sequences together to get a single, combined, spread sequence.[34]

45. Kaiser's spreading technique was different from the linear precoder of the applicant's invention. The applicants' invention operated on a block of input values by creating weighted sums of those values without the need for any spreading step or the use of binary chips. In responding to the rejection, the applicants stated that Kaiser's technique, which included applying a spreading sequence of chips to an information bearing symbol was not a "linear transformation" within the meaning of their claims:

> "The operation [in Kaiser's spreading and sequence imposition unit] of spreading a single information-bearing symbol over a set (L) of data

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[32] *E.g.*, https://www.electronics-notes.com/articles/radio/dsss/what-is-direct-sequence-spread-spectrum.php.
[33] Ex. K at 5:33-50, Figures 2 and 4.
[34] Ex. K at 5:33-50, Figures 2 and 4.

> symbols ***is different from linearly precoding*** a complex field of each original symbol ***(i.e., applying a linear transformation)***…. ***There is no evidence of record to indicate that applying a spreading sequence linearly transforms*** the complex field of the information-bearing symbols at all.[35]

46. In my opinion, a person having ordinary skill in the art would understand that the inventors clearly and unmistakably distinguished Kaiser's technique of using binary chips to spread each symbol into a spread sequence from the claimed linear transformations. In particular, such a person would understand that the language "spreading a single information-bearing symbol over a set (L) of data symbols" was a characterization of Kaiser's system, in which each input symbol intended for transmission (i.e., "single information-bearing symbol") was "spread over a set of (L) data symbols" (i.e., transformed into a transmission sequence of L symbols, using a spreading sequence of chips).

47. I further understand that the Defendants contend that the term "linear transformation" as used in the '230 patent requires a "time invariant" linear transformation. The ordinary meaning of "linear transformation" does not require that it be time invariant. To the contrary, multiple academic papers disclose and analyze the use of a "time varying linear transformation."[36] Moreover, the '886 provisional application,

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[35] Ex. M at UMN0000233 (true and correct excerpt from the '768 Patent File History, Office Action response dated Jan. 5, 2006).

[36] *E.g.*, Ex. N at abstract (Gao & Zhou, "Secure MIMO communication system based on time varying linear transformation," *Proceedings of Third Int'l Conf. on Wireless, Mobile and Multimedia Networks* (2010)); Ex. O at 90 (Gao, "A Novel MIMO communication system based on time varying linear transformation and Tanner codes," *Proceedings of 2010 IEEE 10th Int'l Conf. on Signal Processing* (2010)); Ex. P at 486 (Chen, et al., "Turbo Space-Time Codes with Time Varying Linear Transformations," *IEEE*

which is incorporated by reference into the '230 patent specification, expressly states that "time-varying precoders may be useful for certain purposes."[37] For these reasons, it is my opinion that the person of ordinary skill in the art would not understand that the term "linear transformation" was intended to be limited to "time invariant" linear transformations, and would, in fact, understand the term to include both time varying and time invariant linear transformations, consistent with its ordinary meaning.

B. Interleaver Terms

48. Several claims include the terms "interleaved" or "interleaver." Both terms refer to a process of interleaving, which is a well-known class of techniques in the field of digital wireless transmission systems. A person of ordinary skill in the art would understand the ordinary meaning of "interleaving" to be a process that shuffles or reorders individual pieces of data, such as bits or larger symbols, prior to transmitting them.[38] Interleaving makes coded data more robust by dispersing the redundant data in the data stream, making it more likely that a temporary problem in the signal transmission will not prevent at least some of the redundant data from reaching the receiver.

Transactions on Wireless Comm. (2007)); Ex. Q at 280 (Zhou, "A novel space-time LDPC code with Time varying precoding," *Proceedings of 2nd Int'l Conf. on Wireless, Mobile and Multimedia Networks* (2008)).

[37] Ex. H at UMN0000966.

[38] Ex. R at UMN0149716 (true and correct copy of Kenneth Andrews, Chris Heegard, & Dexter Kozen, "A Theory of Interleavers," *Technical Report TR97-1634*, Computer Science Dep't, Cornell Univ., June 1997); Ex. S (Frank Hargrave, Hargrave's Communications Dictionary (2001)).

49. An interleaver would be understood by a person of ordinary skill in the art to be a process or electronic hardware that performs interleaving. In addition, "interleaved" would be understood by a person of ordinary skill in the art to be a set of data that has undergone the process of interleaving. Thus, "interleaved symbols" would refer to a block of symbols that have been interleaved, and "interleaved bits" would refer to a block of bits that have been interleaved. A "symbol interleaver" would be understood by a person of ordinary skill in the art as a process or circuit that takes a block of symbols and interleaves it.

50. Interleavers come in a variety of forms. One type of interleaver, called a "block interleaver," rearranges a block of data by reading the data into an array of rows and columns and then reading it out again. For example, the data is read in on a row-wise basis and then read out on a column-wise basis. This ensures that every pair of adjacent values in the input block will be separated from each other in the output block by the width of the rows of the array. By contrast, a random interleaver rearranges the values of the input block in a pattern based on the value of a random number.[39] In a random interleaver, the values are rearranged, but there is no guarantee that all adjacent values in the input will be separated in the output. Both the '230 and '768 patents disclose random interleavers as preferred embodiments.[40]

51. Other types of interleavers may interleave groups of values, rather than individual values, from the input. For example, the LTE cellular communication

[39] Ex. R at 1.
[40] '768 Patent at 10:65-11:2; '230 Patent Cert. of Correction at 11.

standard prescribes the use of an interleaver to rearrange a block of symbols associated with the physical downlink control channels.[41] The specification directs that the symbols in the input block be grouped into blocks of four symbols called "quadruplets," which are then rearranged by an "interleaver." The interleaver changes the relative positions of respective quadruplets, and thus rearranges the positions of symbols within the block. This use of the term "interleaver" in the LTE standard is consistent with the plain and ordinary meaning of that term as it would be understood by a person of ordinary skill in the art.

52. While an interleaver is typically used in a transmitter to reorder bits or symbols prior to transmitting them to a receiver, when those bits or symbols are received at the receiver, it is typically necessary to reverse the interleaving process to restore the transmitted data to its original order. Such a process is known as de-interleaving, and a process or electronic hardware that accomplishes such de-interleaving is known as a de-interleaver.

C. Unitary Matrix Terms

53. Certain claims of the '230 and '768 patents include the phrases "applying a unitary matrix" and "linear precoder comprises a unitary matrix."[42]

54. A "unitary matrix" is a well-defined, standard mathematical term that refers to matrices having complex values such that the inverse of the matrix equals its conjugate transpose. The inverse of a matrix A (denoted A^{-1}) is a matrix that satisfies the equation

[41] Ex. U at TS 36.211 V10.0.0 (2011-01) Section 6.8.5.
[42] '768 Patent claim 18; '230 Patent claims 3 and 18.

$A*A^{-1} = I$, which I is an identity matrix (a matrix having only ones on the diagonal and zeros everywhere else). A conjugate transpose of a matrix is matrix in which each complex entry in the original matrix is replaced with its complex conjugate, and then the entire matrix is transposed. The complex conjugate of a complex number a+bj equals a-bj (where j = the square root of -1). Transposing a matrix means making each row into a column, and vice versa. For example, the '768 patent teaches that precoders based on unitary matrices do not change the Euclidean distances between M-dimensional vectors, and thus do not alter performance when the channel is purely AWGN (with no fading).[43] In my opinion, the term "unitary matrix" is used in the '768 and '230 patents consistent with its ordinary meaning.

55. As discussed above, a matrix is a convenient mathematical shorthand or abstraction that allows certain types of arithmetic relationships to be expressed in a succinct way. For example, in the field of digital signal processing, it is common to perform mathematical transformations on blocks of data that are most easily described in terms of multiplication by one or more matrices. These are described throughout the five patents-in-suit. But because matrices are mathematical abstractions, it is generally understood, including by those of ordinary skill in the field of wireless digital transmissions systems, that describing a transformation in terms of matrices does not require, or imply, any specific way of implementing the transformation in a transmission system. A given transformation defined in terms of matrix arithmetic can be

[43] '768 Patent at 6:44-53.

implemented in a variety of ways—using specialized hardware or in software running on a general-purpose computer. The choice of implementation is an engineering decision based on considerations such as speed and expense. What is important is that the output of the transformation have a particular relationship to the input.

56. Consistent with the above, it is my opinion that a person having ordinary skill in the art would interpret the references to matrix multiplication in the patents-in-suit to be descriptions of mathematical transformations that can be implemented in a variety of ways, not on a specific implementation of those relationships. More particularly, it is my opinion that a person of ordinary skill in the art would understand those descriptions to encompass a variety of potential software or hardware implementations that transform data in a way such that the transformation can be described as a matrix multiplication. Similarly, such a person would understand the references in the claims to transformations or precoders that comprise a particular type of matrix, such as a unitary matrix, to be referring to a variety of potential software or hardware implementations that could be described in terms of matrix multiplication.

D. Multiple Matrices Terms

57. The ’230 patent describes, in one embodiment, a class of precoders, LCP-B, having a precoder matrix that is itself defined as the product of two component matrices. The first matrix is an IFFT matrix referred to by the symbol $F_{N_t}^T$, and the second matrix is a diagonal matrix with its diagonal values defined as an exponential series $(1, \alpha, \ldots, \alpha^{N_t - 1})$. A number of the claims of the ’230 patent similarly describe a linear transformation that are based on two matrices.

58. As previously discussed, a person of skill in the art would understand that the use of matrices to define a linear transformation does not require any particular implementation, so long as the data is transformed as defined by the matrices. Thus, a reference in the '230 patent to a linear transformation that is based on certain matrices would be understood by a person of ordinary skill in the art to refer to a variety of potential software or hardware implementations of the defined linear transformation. In other words, it would refer to a transformation that includes a mathematical operation that can be described by the specified matrix expression.

59. I understand that the Defendants contend that certain expressions used to define the types of matrices on which a linear transformation may be based are indefinite. Specifically, Defendants contend that the following claim terms are indefinite:

- "wherein the linear transformation is based on multiple matrices …"
- "wherein the first matrix is based on a fast Fourier transform (FFT) matrix, and wherein the second matrix is based on a diagonal matrix"
- "wherein the linear transformation is based on a Fourier transform"

60. I am advised that a term is indefinite if it does not inform, with reasonable certainty, those skilled in the art about the scope of the invention. In my opinion, a person having ordinary skill in the art would understand the meaning and scope of these terms, with reasonable certainty.

1. "wherein the linear transformation is based on multiple matrices"

61. As discussed above, it is my opinion that a person of ordinary skill in the art, when reading the claims of the '230 patent in view of the specification, would understand, with reasonable certainty, that references in the claims to a linear

transformation that is "based on" multiple matrices refer to transformations defined in terms of matrix multiplication. Moreover, such a person would also understand that a transformation defined in that manner would, in view of the specification, be referring to a transformation defined in terms of a matrix that was itself the product of multiple matrices. (Under the rules of matrix arithmetic, any expression of the form A*B*C can be written as D*C, where D = A*B. Thus, it is the same as saying that the transformation was defined in terms of multiplication by two or more matrices.) Because a person of ordinary skill would understand this intended meaning with reasonable certainty, I do not agree that this term is indefinite. Rather, it would be understood to mean that "the linear transformation can be described as multiplication by a matrix that is the product of at least two other matrices comprising a first matrix and a second matrix."

2. "wherein the first matrix is based on a fast Fourier transform (FFT) matrix, and wherein the second matrix is based on a diagonal matrix"

62. The phrase "wherein the first matrix is based on a fast Fourier transform (FFT) matrix, and wherein the second matrix is based on a diagonal matrix" appears in the same claims as the previously discussed limitation. The phrase identifies the required characteristics of two of the "multiple matrices" of the linear transformation.

63. The first characteristic is that one of the matrices is based on a fast Fourier transform (FFT) matrix. The term "fast Fourier transform" refers to a well-known class of algorithms for implementing a mathematical transform called a "Discrete Fourier Transform" (DFT). A DFT is normally defined by a matrix having complex exponential values, which is referred to as a "DFT matrix." In digital signal processing applications,

DFTs are almost always computed using the FFT algorithm, and so the term "FFT matrix" may be used interchangeable with DFT matrix. All of this would be known to a person having ordinary skill in the art of digital wireless communications systems.

64. A person of ordinary skill in the art would know that an FFT matrix is a square matrix of size NxN, where N is an integer, and has the following properties: The first row, and the first column are all ones, and the remaining values can be expressed as $\omega^{(j-1)(k-1)}$, where j is the row and k is the column of a particular value and $\omega = e^{-2\pi j/N}$. In some applications the values of the FFT matrix may all be scaled by $\frac{1}{\sqrt{N}}$. A variant of the FFT matrix is called the "inverse fast Fourier transform (IFFT)" matrix, which has a very similar form, except that $\omega = e^{2\pi j/N}$. (Note that the sign of the exponent is entirely conventional and may be reversed for some applications.) Because of this, it is reasonable to consider an IFFT matrix to be a type of FFT matrix. This is confirmed by the '230 patent specification, in which the example that supports the claimed FFT matrix is referred to as an IFFT matrix.[44] Thus, a person of ordinary skill in the art would understand with reasonable certainty what kinds of matrices fall within the claimed category of "FFT matrix."

65. The second recited characteristic is that the second matrix must be based on a "diagonal matrix," namely one that has non-zero values in its diagonal elements, and zeros everywhere else. A diagonal matrix is a well-known mathematical concept and a

[44] '230 Patent Cert. of Correction at 6; '230 Patent Claim 30.

person having ordinary skill in the art would understand the scope of this category with reasonable certainty.

3. "wherein the linear transformation is based on a Fourier transform"

66. Like the term discussed previously, this term requires that the linear transformation involve a Fourier transform. Unlike the prior limitation, however, it does not expressly limit the transform to one defined by an FFT matrix. It also does not require multiple matrices. A person of ordinary skill in the art would thus understand this limitation to have its plain and ordinary meaning, namely that the linear transformation be one that can be "expressed as a mathematical operation that includes a Fourier transform."

E. Linear Combination Term

67. Some of the claims of the '230 patent refer to "linear combinations." As would be understood by a person having ordinary skill in the art, a linear combination is a well-defined mathematical term that means the sum of a set of values, where each value may be first multiplied by a coefficient. For example, given three values x1, x2, and x3, a linear combination of those values would be any expression of the form a*x1+b*x2+c*x2, for any values of a, b, and c. A less technical way of describing a linear combination is simply a "weighted sum," which I addressed previously.

F. Subcarrier Term

68. The term "subcarrier" appears in claims of the '230, '317, '185 and '309 patents. In these patents, "subcarrier" is used consistently to refer to one of the carrier

frequencies in a multi-carrier waveform, such as an OFDM waveform. This usage is entirely consistent with the ordinary meaning of the term "subcarrier" in the field of wireless digital transmission systems.[45]

69. I understand that the Defendants propose a construction of "subcarrier" that limits its usage to MIMO (multiple input, multiple output) transmission systems. Such a construction would be contrary to the ordinary meaning of "subcarrier," which in no way is limited to MIMO systems. It is also contrary to the usage of the term "subcarrier" in the patents-in-suit. For example, the primary embodiment of the '768 patent describes an OFDM transmission system without any mention of using multiple antennas.[46] Similarly, the embodiment in Figure 1 of the '230 patent includes OFDM (and thus subcarriers) but does not disclose multiple antennas.[47]

70. That the term "subcarrier" does not inherently refer to a MIMO transmission is further reinforced by the usage of that term in the extrinsic evidence. For example, in a doctoral thesis by Klaus Witrisal, cited by Defendants as relevant extrinsic evidence, the author describes conventional OFDM systems, having subcarriers, and then

[45] Ex. V at UMN0150017 (true an correct copy of excerpts from Cox, An Introduction to LTE: LTE, LTE-Advanced, AEO and 4G Mobile Communications); Ex. W at 1 (true and correct copy of excerpts from Louis Litwin & Michael Pugel, "The Principles of OFDM," *RF Signal Processing*, January 2001); Ex. X at UMN0149562 (true and correct copy of excerpts from Jeroen Theeuwes, Prank H.P. Fitzek, Carl Wijting, "Subcarrier Assignment for ODFM Based Wireless Networks Using Multiple Base Stations," Aalborg Univ., ISBN 87-90834-49-6 (2004).

[46] '768 Patent at 2:16-3:31, 5:4-6, Fig. 1.

[47] '230 Patent at 4:14-44.

proposes an improved OFDM technique using multiple antennas.[48] The author states that "using a set of transmit or receive antennas," a conventional OFDM system can be improved.[49] This statement demonstrates that OFDM systems, including their subcarriers, predate the use of OFDM with MIMO, and thus the ordinary meaning of subcarrier does not require a MIMO system.

G. Phase Rotate Term

71. Several claims of the '230 patent recite the phrase "a diagonal matrix to phase rotate each entry of a symbol vector." Each of those claims requires that the claimed linear transformation be based on two matrices—a first matrix and a second matrix—and this limitation describes a required feature of the second matrix, namely that it be "a diagonal matrix to phase rotate each entry of a symbol vector." The following paragraphs provide background on the mathematical terms "phase rotation" and "diagonal matrix."

1. Diagonal Matrices

72. As discussed previously, a diagonal matrix is a matrix having non-zero values only on its diagonal, which is shown in the following illustration of a 3x3 diagonal matrix:

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[48] Ex. Y at 249, 270 (true and correct copy of excerpts from Klaus Witrisal, OFDM Air-Interface Design for Multimedia Communications (2002), ISBN: 90-76928-03-7)
[49] Ex. Y at 270.

$$A = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 2 & 0 \\ 0 & 0 & 3 \end{bmatrix}$$

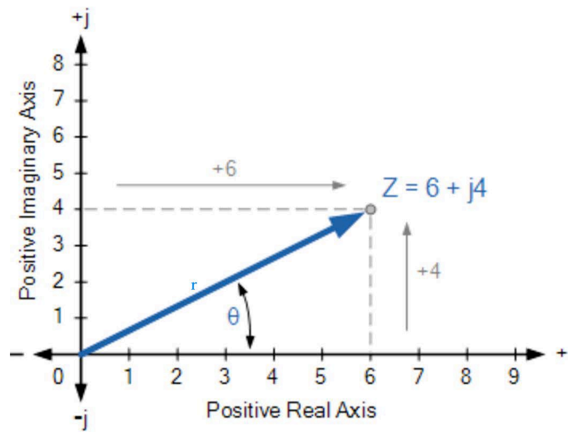
73. An important property of a diagonal matrix is that if an NxN diagonal matrix is multiplied by a vector with N elements, the result is that each element of the vector is multiplied by a corresponding value of the diagonal matrix. Thus, in the example above, if a vector X= $\begin{bmatrix} x1 \\ x2 \\ x3 \end{bmatrix}$ were multiplied by the diagonal matrix A above, the values in the resulting vector A*X would be $\begin{bmatrix} 1 * x1 \\ 2 * x2 \\ 3 * x3 \end{bmatrix}$.

2. Phase Rotation

74. Phase rotation is a mathematical operation that is applicable to complex numbers. Complex numbers are numbers of the form a+b*j, where a and b are real numbers, and j is the square root of -1. (Because the square root of -1 does not exist in ordinary arithmetic, the "b*j" portion of the complex number is referred to as the "imaginary" portion.) Complex numbers are useful for describing certain types of natural phenomena, as well as the behavior of electronic circuits, and are used extensively in the '230 patent to describe the operation of various linear precoders.

75. It is common to represent a complex number as a point (a, b) on a two-dimensional graph called the "complex plane," with the horizontal axis representing the value of a (the "real" portion of the number), and the vertical axis represent the value of b

(the "imaginary portion"). The figure below shows the complex number Z = 6 + 4j on the complex plane.



76. As the figure above illustrates, an equivalent way to describe a complex number is to specify the length (r) and angle (θ, theta) of a line extending from the origin point (0,0) to the point (a,b). The value r in the figure is called the "magnitude" of a complex number, and the angle θ is called its "phase." This way of describing a complex number—sometimes called "polar" notation—is useful because it simplifies certain types of mathematical operations. For example, the product of two complex numbers can be calculated by multiplying their magnitudes and adding their phases. A consequence of this fact is that if a complex number if multiplied by another complex number having a phase other than 0, the resulting product will have a different phase than the original value. This type of operation is sometimes referred to as "phase rotating" the original value, because it can be visualized as rotating the arrow representing the original value about the origin point (0,0) so that it points in a different direction.

3. The ’230 Patent

77. As discussed above, the ’230 patent teaches to use a linear precoder matrix Θ, which is defined as follows: $\Theta = F_{N_t}^T diag(1, \alpha, \ \ldots, \ \alpha^{N_t-1}), \alpha := e^{j2\pi/P}$. The ’230 patent describes the use of this matrix as a precoder as being equivalent to “phase-rotating each entry of the symbol vector s, and then modulating in a digital multi-carrier fashion, that is implemented by $F_{N_t}^T$.”[50] What this means is that the application of the matrix Θ is mathematically equivalent to applying two matrices to a vector of symbols – first applying diagonal matrix, which “phase-rotat[es] each entry of the symbol vector” and then the matrix $F_{N_t}^T$, which performs “digital multi-carrier” modulation.

78. The effect of multiplying an input vector by this diagonal matrix is to multiply each symbol in the vector by a respective one of the diagonal values of the matrix, *i.e.*, by one of $1, \ \alpha, \ \ldots, \ \alpha^{N_t-1}$. Because each of those diagonal values is a complex number with a different phase, the effect of this operation is to change the phase of each of the input symbols by a different amount. Importantly, however, the phase of the first diagonal value, “1”, is zero, which means the phase of the first symbol in the input vector does not change from its original value.

79. The purpose of the phase rotation matrix in the disclosed precoder is to increase a characteristic of the precoded values known as “diversity.” In this context, diversity means having symbols with a multiplicity of differing phases. In addition, diversity can be increased by incrementing the phases of the input symbols by different

[50] ’230 Patent Cert. of Correction at 6.

amounts. This, in turn, improves the ability of receiver to accurately decode symbols transmitted over a MIMO-type transmission system.

H. Null Subcarrier Term

80. The term "null subcarrier" is used in the '317, '185, and '309 patents to refer to a subcarrier in a multi-carrier transmission system in which no value is intended to be transmitted during a specific time. For example, the specification states that "each subcarrier corresponding to a zero symbol is referred to as a null subcarrier."[51] In the context of the '317, '185 and '309 patents, a person of ordinary skill in the art would have understood a "zero symbol" to mean the transmission of no energy or value on a particular subcarrier. This would mean that no value would be received on that subcarrier by the receiver.

81. I understand that the Defendants contend that a "null subcarrier" must, by definition, always be used to estimate carrier frequency offset (CFO).[52] I disagree. Nothing in the ordinary meaning of those words implies estimation of carrier frequency offset. To the contrary, the term is often used in the art in ways that have nothing to do with estimating carrier frequency offset. For example, in the WiMAX wireless communication standard, OFDM signals include null subcarriers. But these null

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[51] '317 Patent at 5:39-41.

[52] CFO is the difference between the assigned radio frequency for communications between a transmitter and receiver, and the frequency of the signals that are actually communicated. This difference, which may be caused by slight hardware imperfections or by a moving receiver, can create transmission errors unless the receiver corrects for it.

subcarriers are used as guard bands, and not for carrier frequency offset estimation.[53] A paper by Hu, et al. suggests using null subcarriers in an OFDM system to reduce the peak to average power ratio, another application having nothing to do with estimating carrier frequency offset.[54] In the 802.16a standard, the term "null carrier" refers to a subcarrier with "no transmission at all."[55]

I. Symbol Adjacency Term

82. Dependent claims in the '185 and '309 patents recite the phrase "inserting at least one training symbol adjacent to at least one null subcarrier." The term is a further limitation on the requirement (found in certain independent claims) of inserting "training symbols and null subcarriers within two or more blocks of … information bearing symbols."[56] As discussed previously, a "training symbol" is a term of art in the field of communication systems, which refers to a symbol having a predefined value that is transmitted by the transmitter to enable a receiver to determine a parameter that can be used to decode other transmitted symbols.

83. I understand Defendants' proposed construction of "training symbol" is "a symbol with a predefined value that can be used by the device that receives the symbol to

[53] Ex. Z at UMN0150035 (true and correct copy of National Instruments, "OFDM and Multi-Channel Communication Systems," http://www.ni.com/white-paper/3740/en/ (2014)).
[54] Ex. AA at 289-305 (true and correct copy of Hu, et al., "Nonlinearity Reduction by Tone Reservation with Null Subcarriers for WiMAX System," Wireless Personal Communications, Vol. 54, Issue 2, (2010)).
[55] Ex. BB at 132 (IEEE Draft Standard for Local and Metropolitan Area Networks – Part 16 (802.16a) dated February 7, 2002).
[56] '185 Patent Claim 1; '309 Patent Claim 16.

determine a physical characteristic of the transmitted signals." This construction is overly broad, because it merely requires that training symbols be usable to determine "physical characteristics of the transmitted symbols." But any reception at a receiver of a transmitted symbol inherently involves determining some "physical characteristic" of that symbol, and so Defendants' construction reduces "training symbol" to any symbol with a predetermined value, a construction that is inconsistent with its ordinary meaning and reads out the word "training" entirely.

Pursuant to 28 U.S.C. § 1746, I declare under penalty of perjury that the foregoing is true and correct.

Executed: November 3, 2021

Jonathan Wells, Ph.D.